



Development of Actinic Mask Inspection

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OUTLINE

1. Introduction
2. Recent activity of EUV Microscope
3. Coherent EUV Scatterometry Microscope
4. Summary

Introduction: **Center for EUV Lithography**

NewSUBARU Synchrotron Radiation Facility



Reflectometer (BL10)

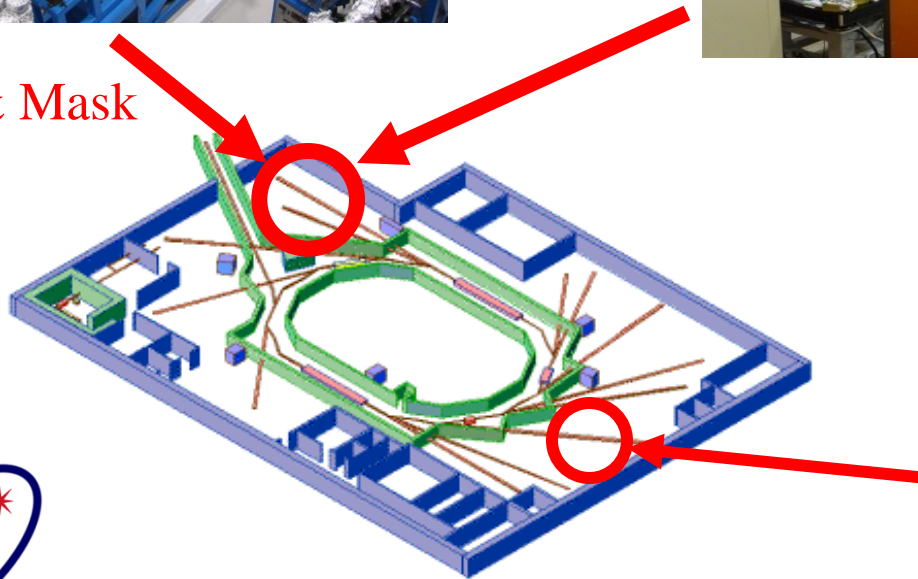


**Interference Lithography &
New Resist evaluation system (BL9)**



Resist

Resist & Mask

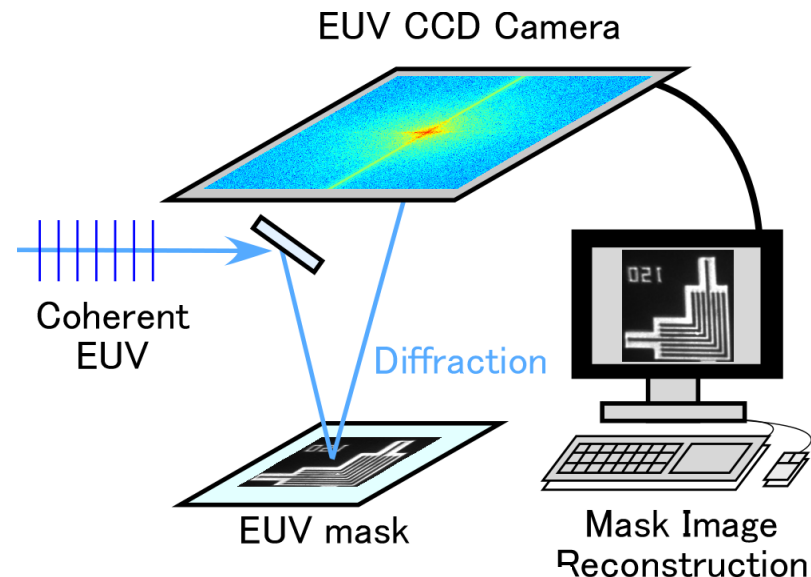
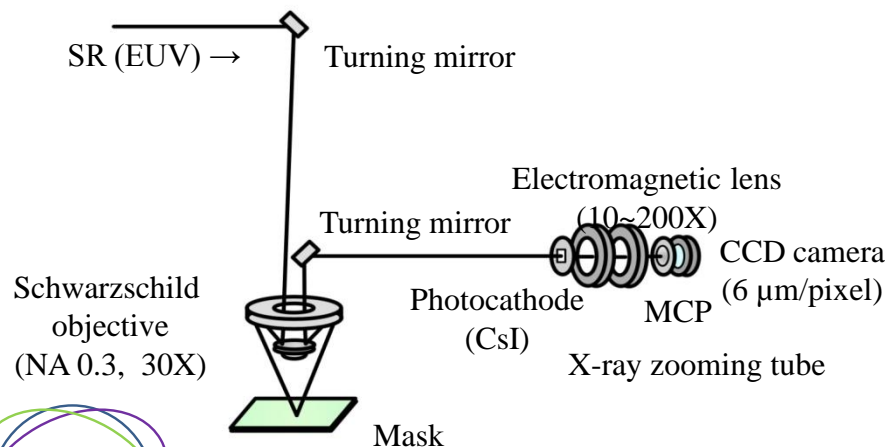
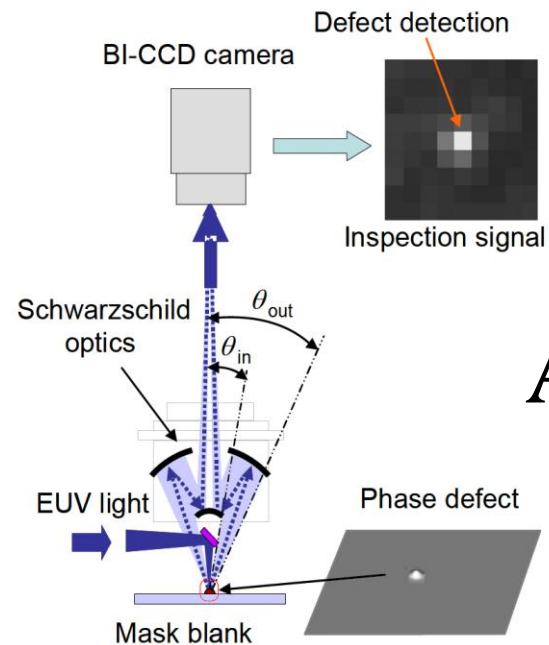
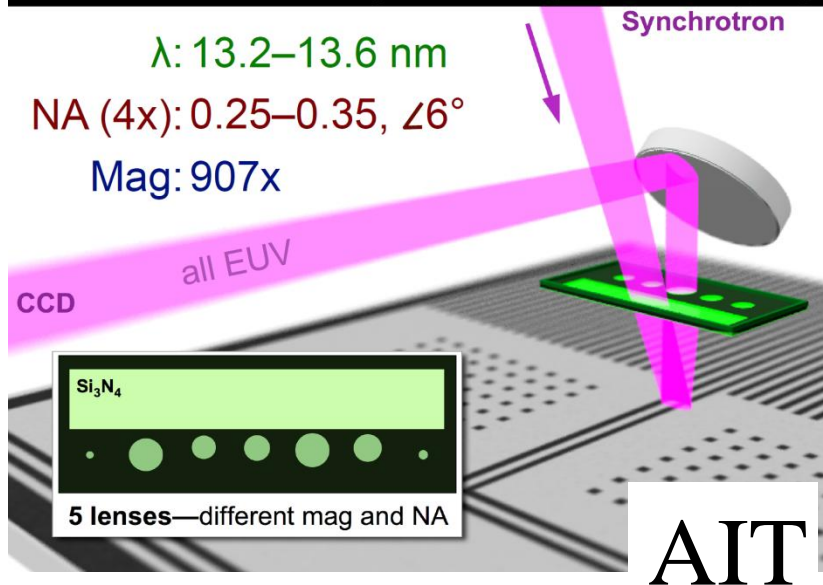


EUVM & CSM (BL3)



Mask

The SEMATECH Berkeley Actinic Inspection Tool (AIT)

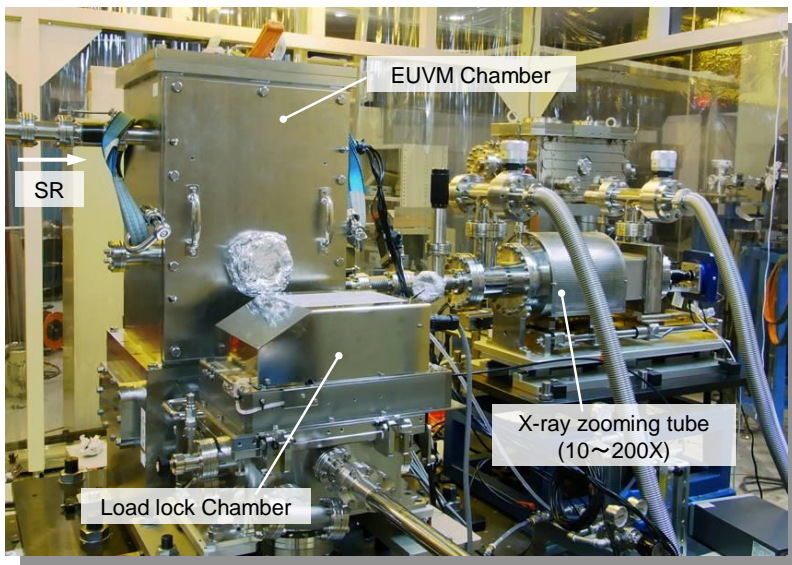
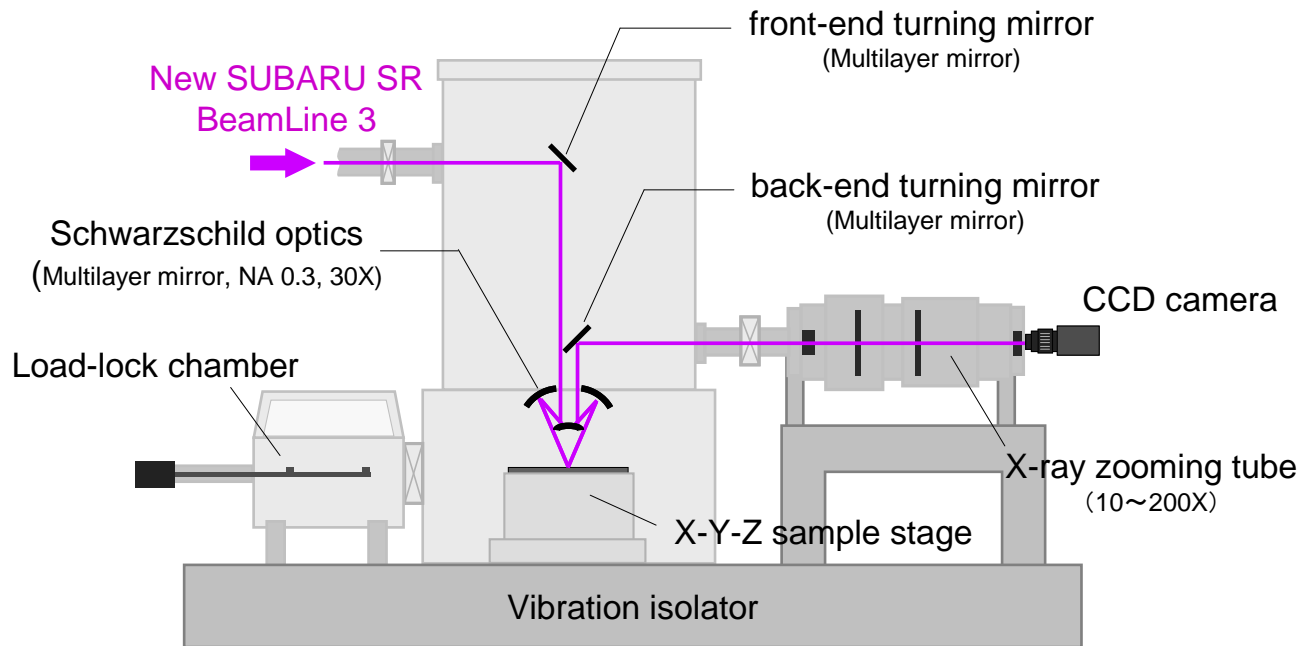


Comparison of Actinic Inspection System

	AIT	ABI	EUVM	CSM
Source	SR	DPP	SR	HHG
Object	Finished Mask Pattern	Blanks Phase Defect	Finished Mask Pattern & phase defect	Finished Mask Pattern defect & CD
Resolution	60 nm	W40nm,H1nm	100nm W20H1nm	2nm downsizing defect
Speed	N/A	4 hours/mask	N/A	N/A
Bright field / Dark	Bright field	Dark field	Bright field	Bright field

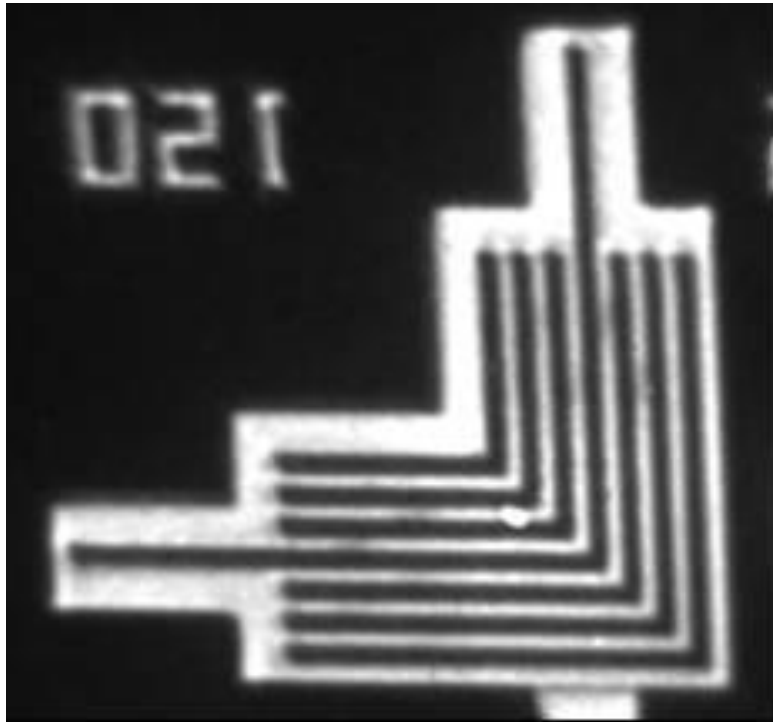


BL-3

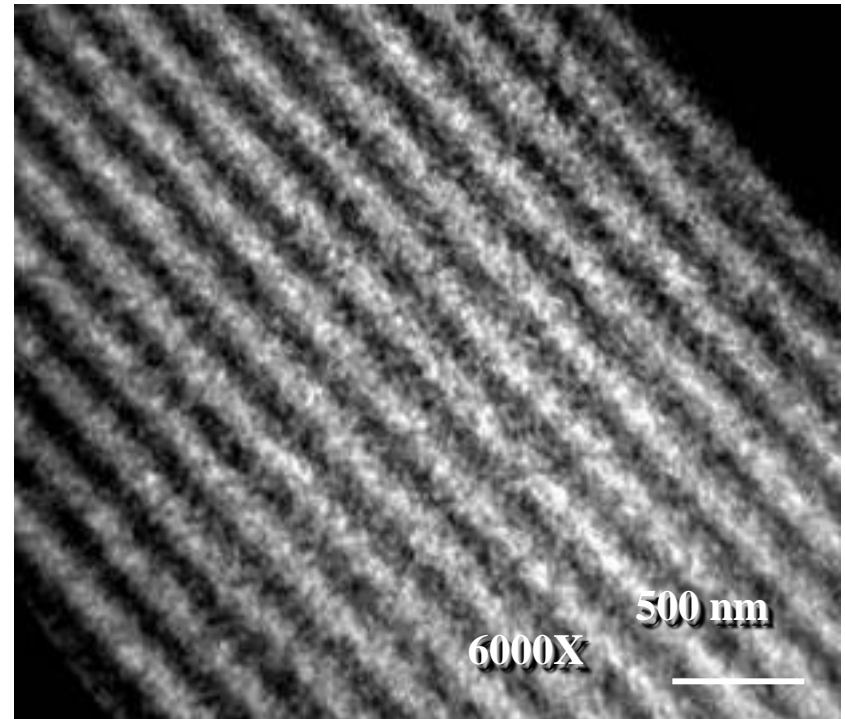


Light Source :	BL-3 Bending magnet
Detection method :	Bright field
Inspection period :	10 ~ 20 s / shot
Magnification :	300 ~ 6000 倍
Resolution :	50 nm (NA 0.3)
Vacuum pressure :	2.0×10^{-5} Pa

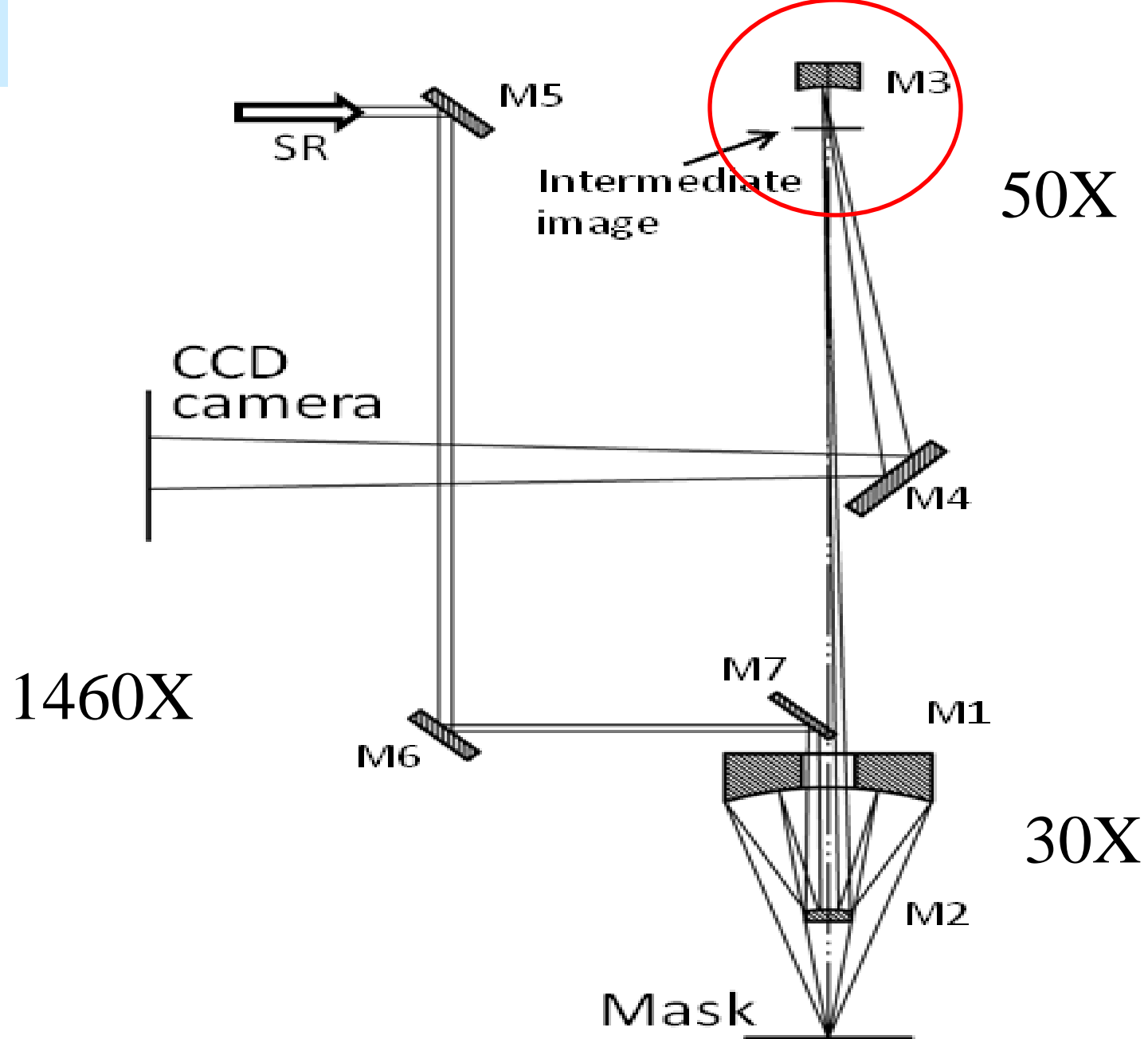
Elbow pattern



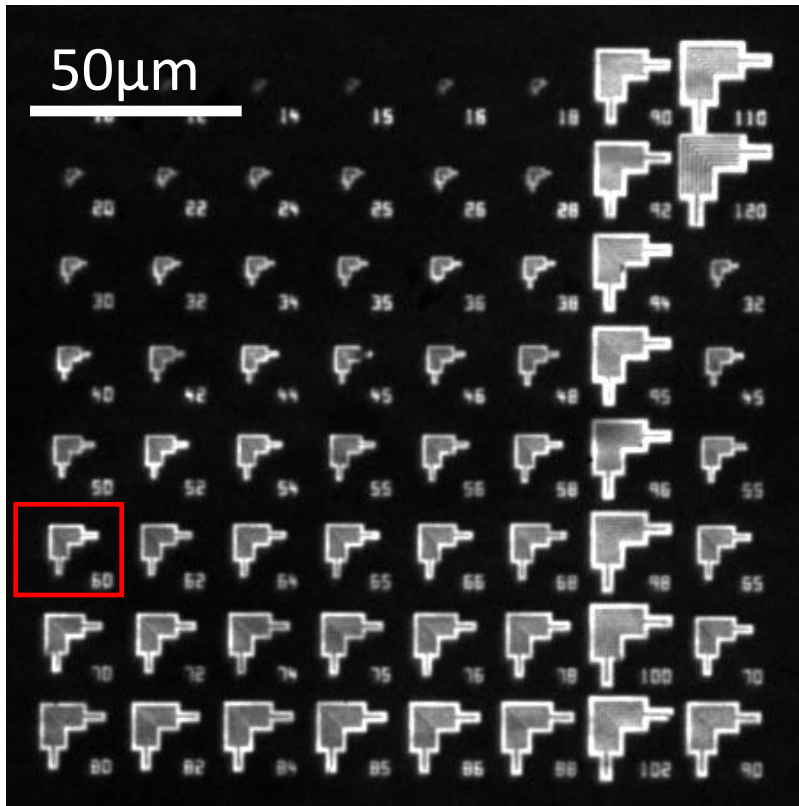
100 nm Lines and spaces



EUVM

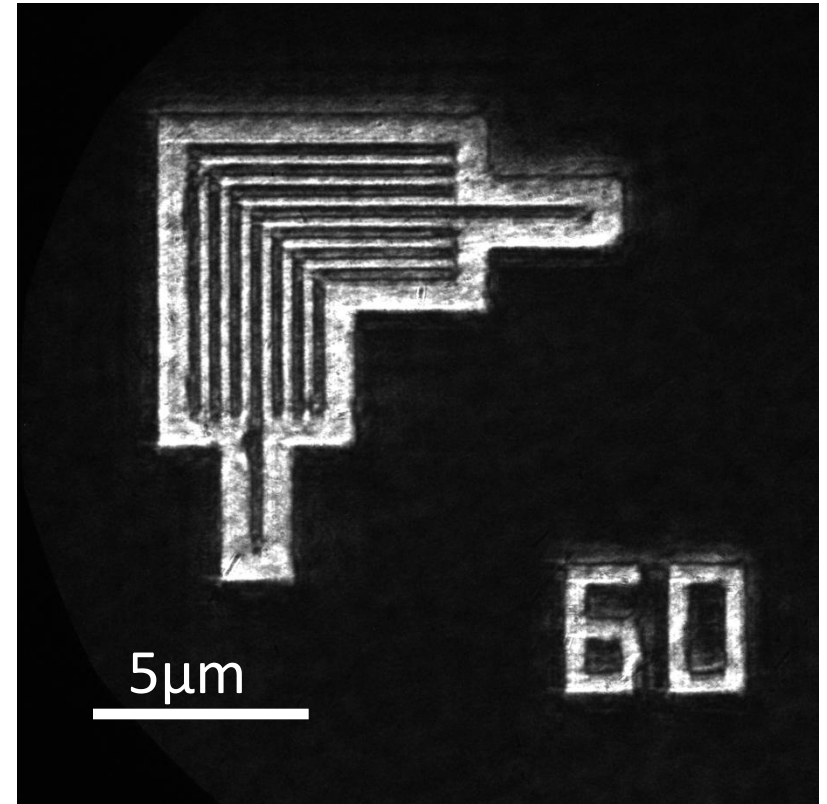


Confirmation of the magnification enhancement



Intermediate image (m=30)

Exp. time: 0.25 sec.



Final image (m=1460)

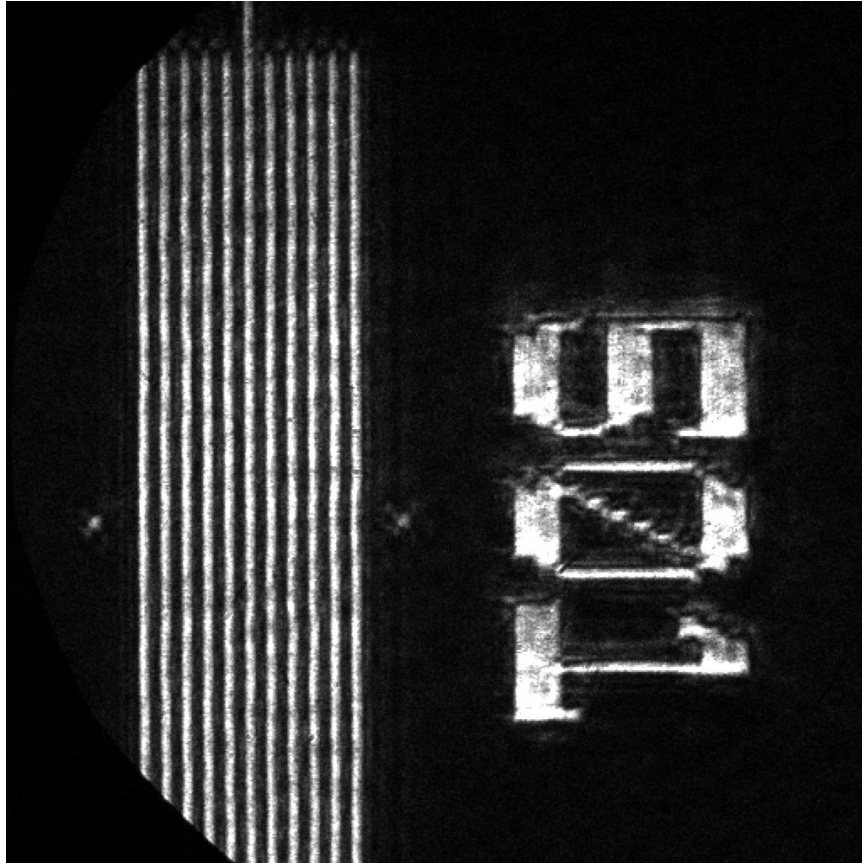
Line width: 240nm (60nm)

Exp. time: 36 sec.

EUV-CCD camera: pixel size 13.5μm, 2048 × 2048 pixels

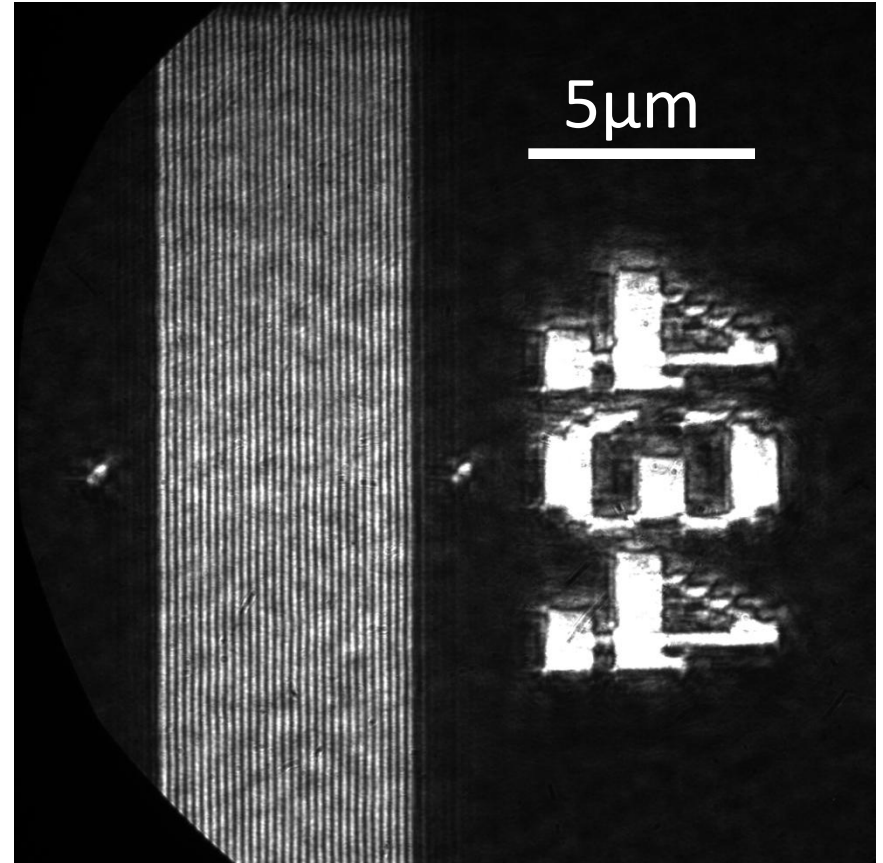
Resolution measurement with L/S patterns

High magnification images ($m=1460$)



Line width: 225nm (56nm)

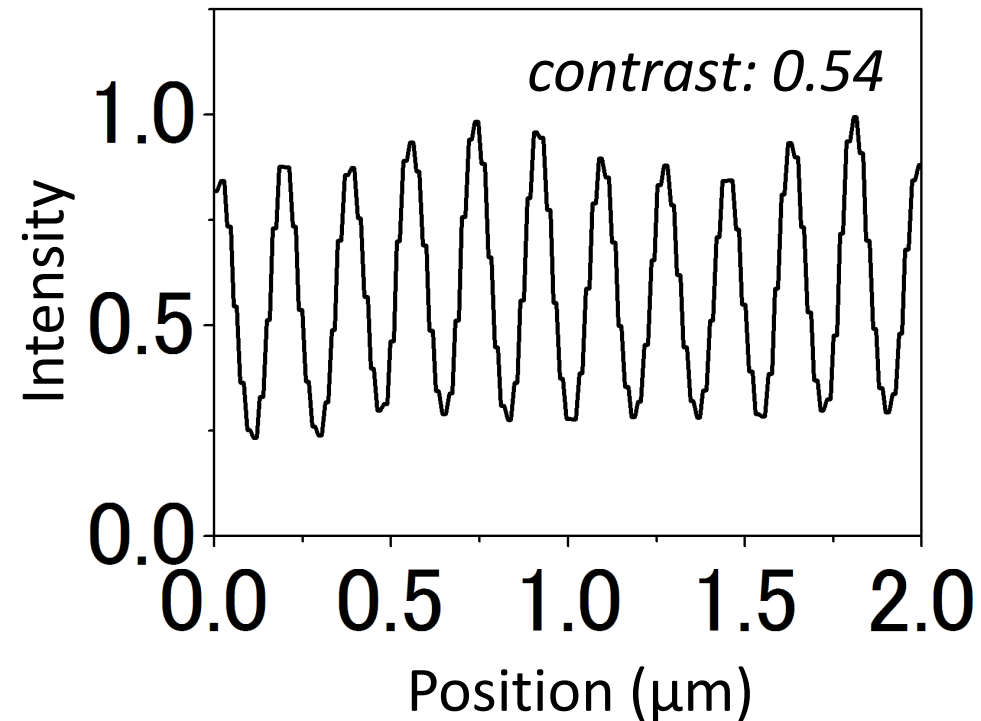
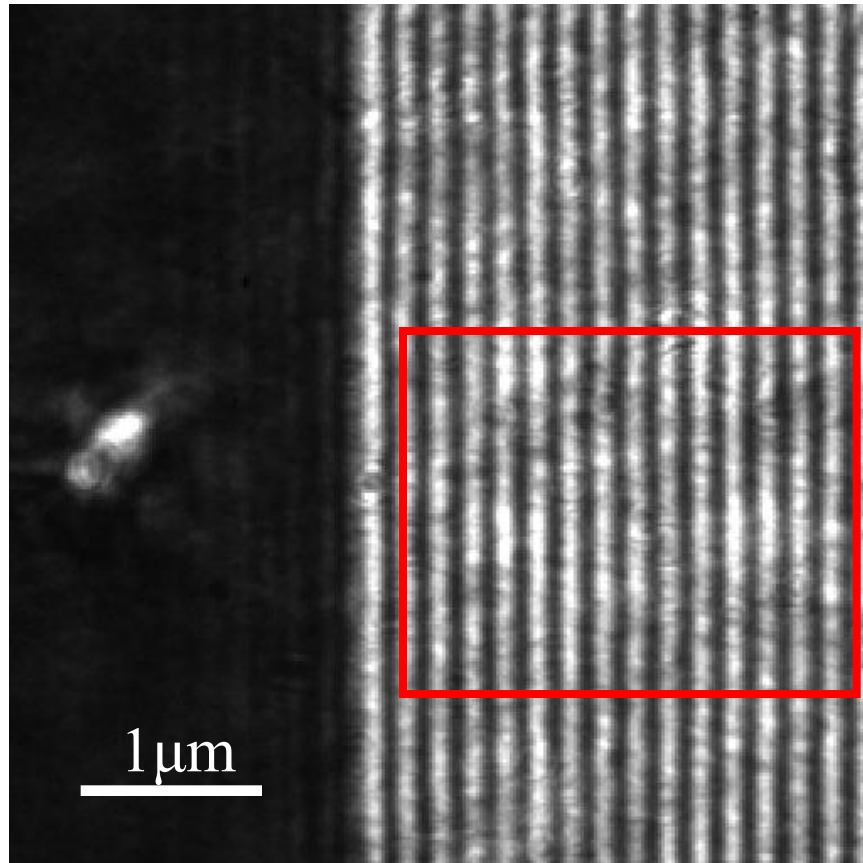
Exp. time: 10s



Line width: 88nm (22nm)

Exp. time: 100s

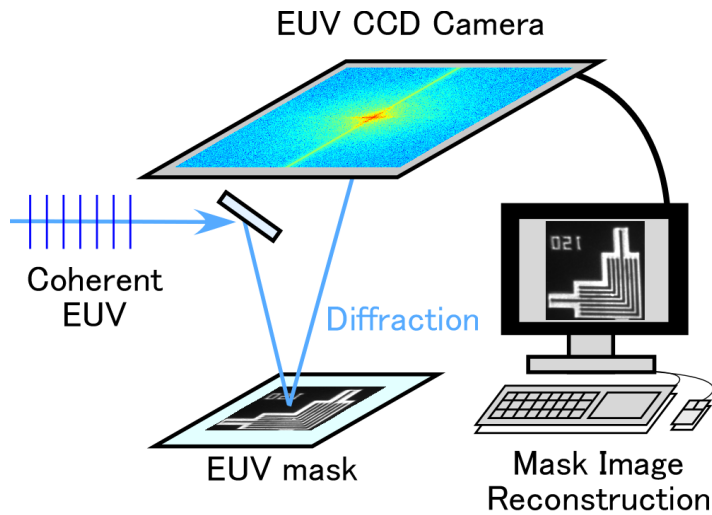
Resolution measurement with L/S patterns



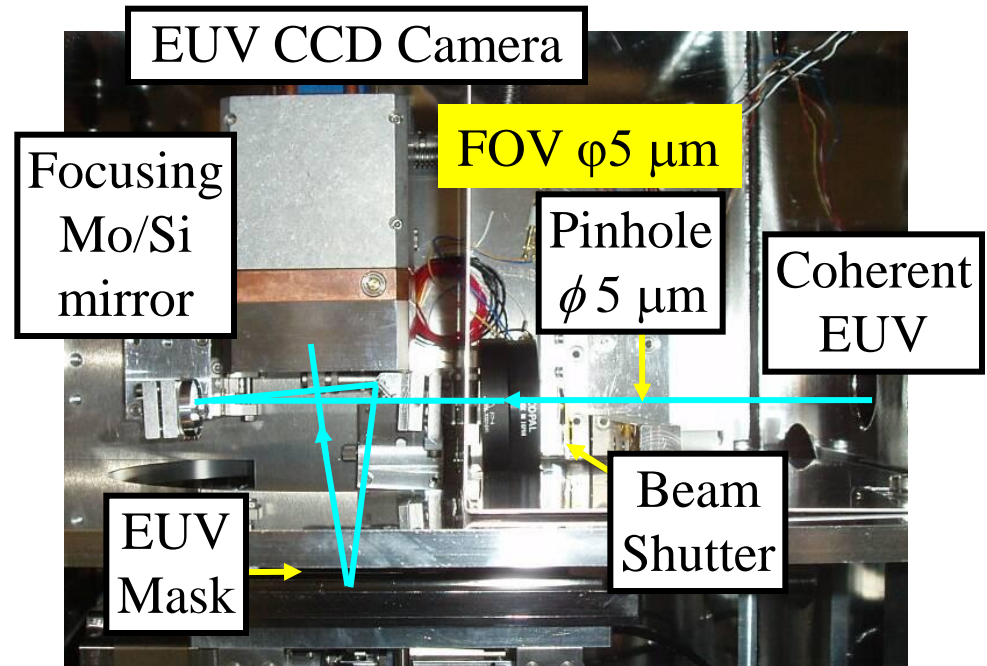
- ✓ 88nm-width L/S pattern was clearly observed.
- ⇒ The capability of inspecting 22nm-node masks.

CSM

Coherent EUV Scatterometry Microscope (**CSM**)



Very Simple



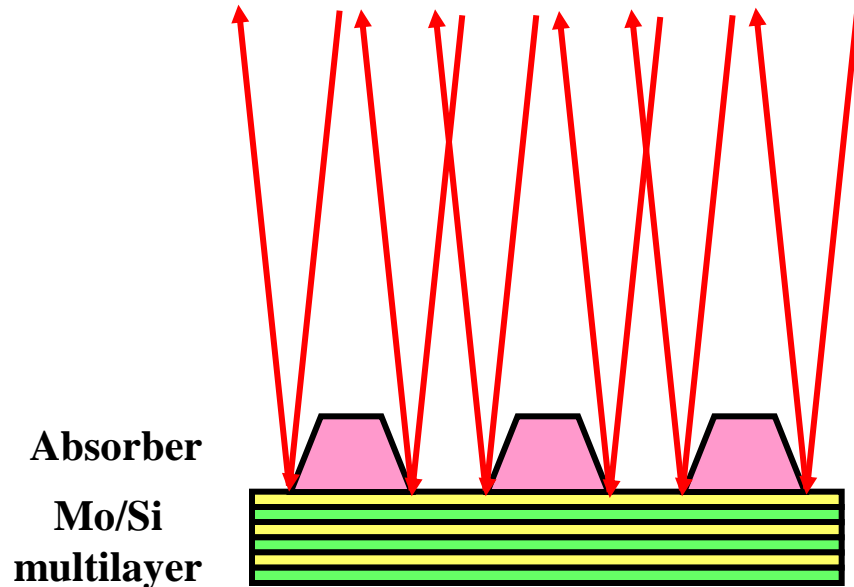
**CD on resist
Evaluation**

+

**Defect
Inspection of
Absorber pattern
& Phase defect**

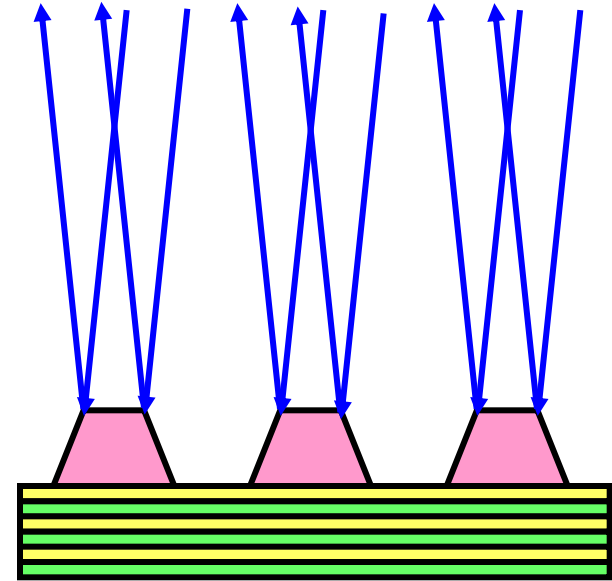
- **EUV ACTINIC** observation
- **LENSLESS** system (Diffraction & Scattering)
- Real space image (pattern image) & CD values are calculated with the diffraction image.
- **COHERENT EUV light** is required. (SR source)

Measurement principle



CSM

**Detects the size of
Mo/Si multilayer.**



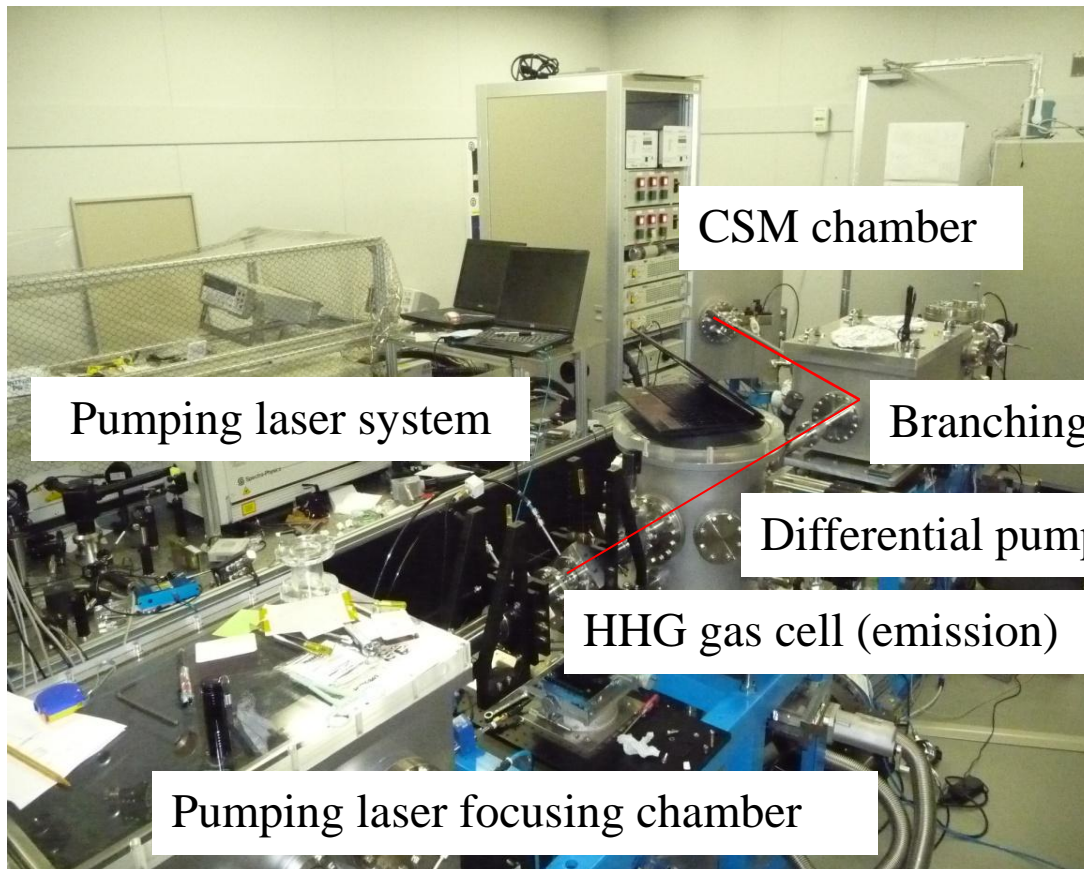
SEM

**Detects the secondary electron
of the top of absorber.**

**The case of a side wall has the inclination, the measure of the
SEM will be smaller than the measure of the CSM.**

CSM CSM with high harmonic generation (**HHG**)

- EUVL is going to the HVM stage.
- EUV mask should be evaluated at the factory using **standalone system**.
- **High-Harmonic-Generation** (HHG) EUV source is standalone and coherent EUV source.



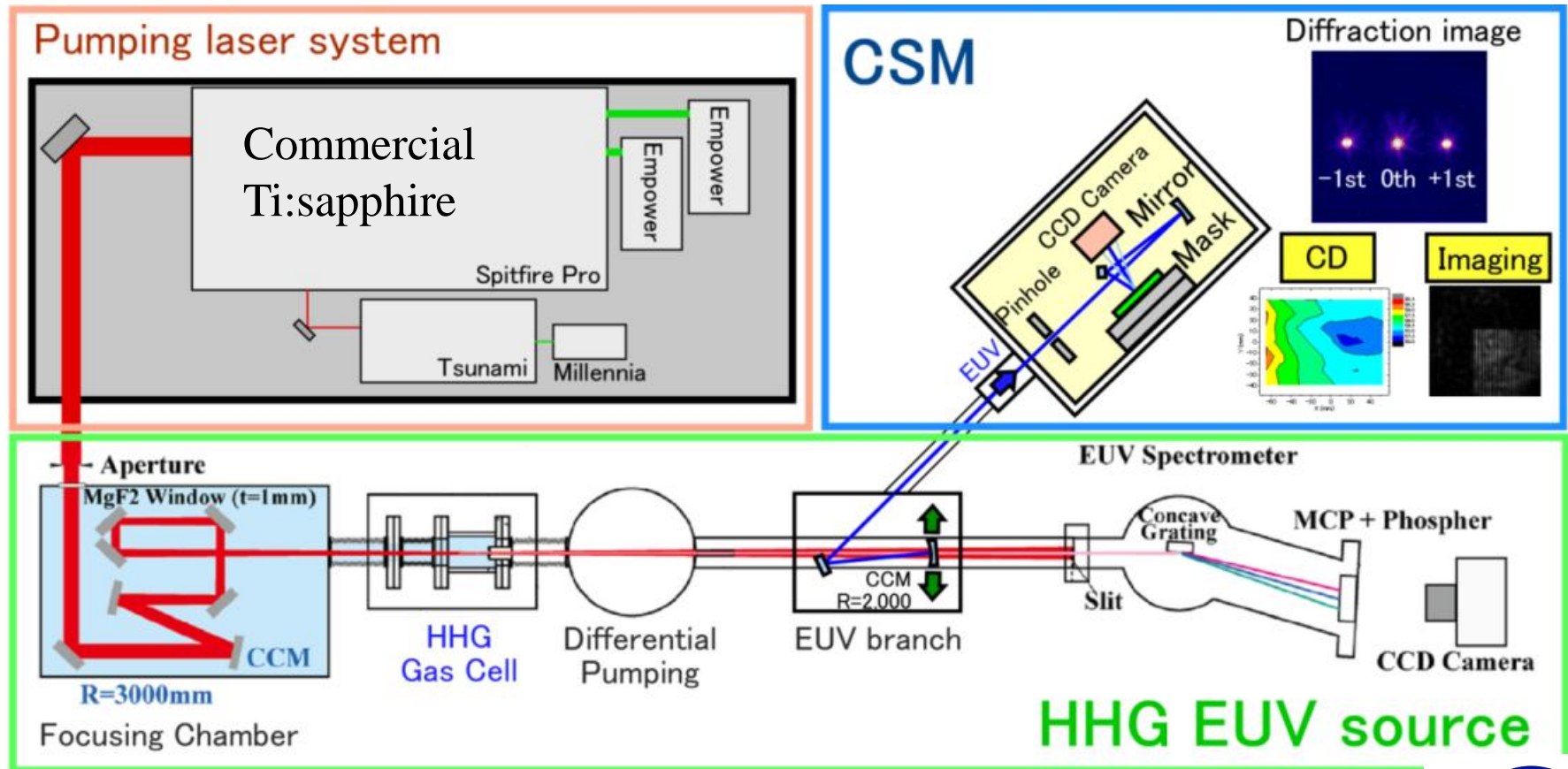
Laboratory scale system
Laser table: $3 \times 1.5 \text{ m}^2$
Room size: $8 \times 4 \text{ m}^2$

Carbolated work
with RIKEN



Schematic of High Harmonic generation CSM

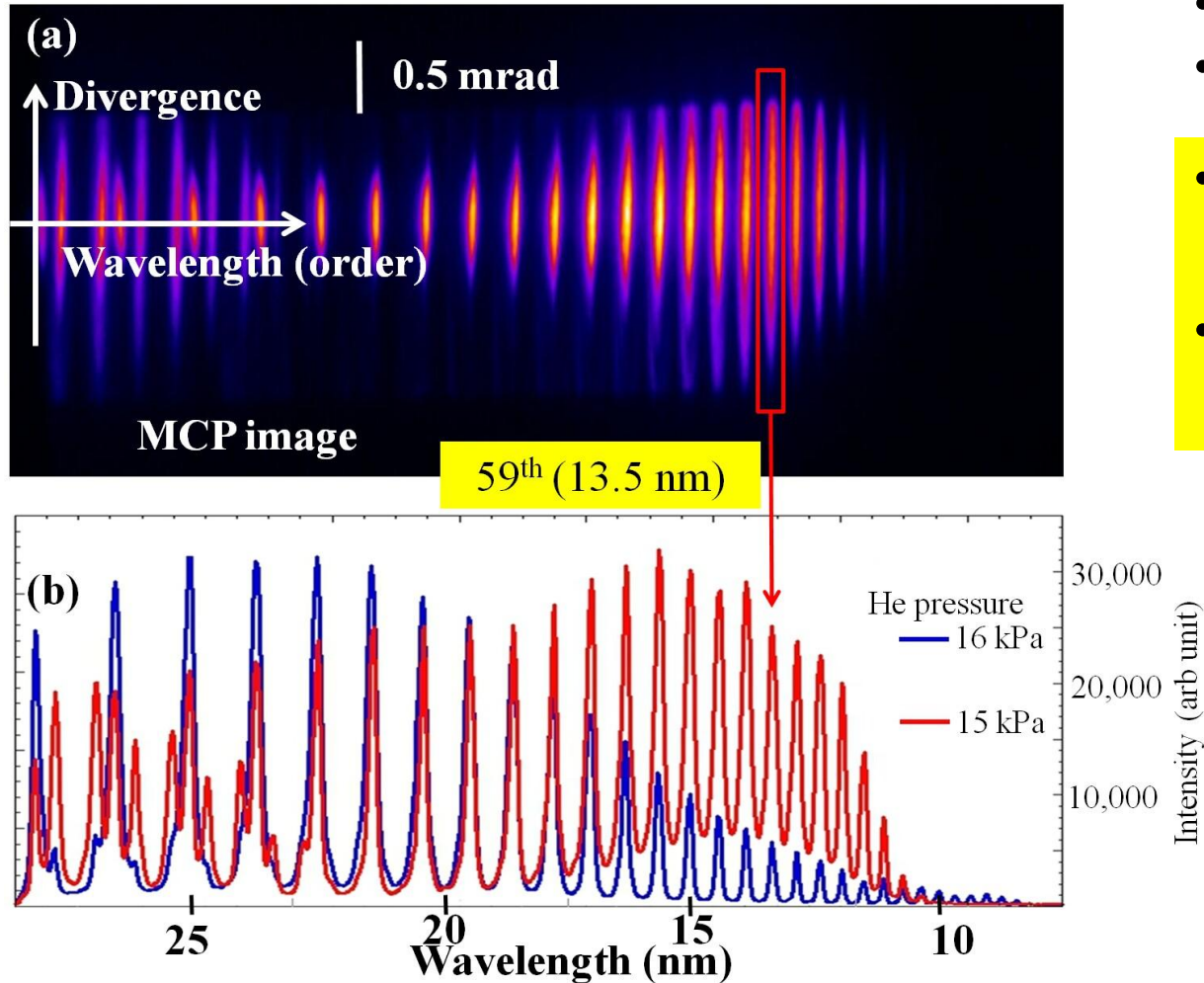
CSM CSM with high harmonic generation (**HHG**)



Schematic structure of HHG-CSM system.

Carbolated work
with RIKEN





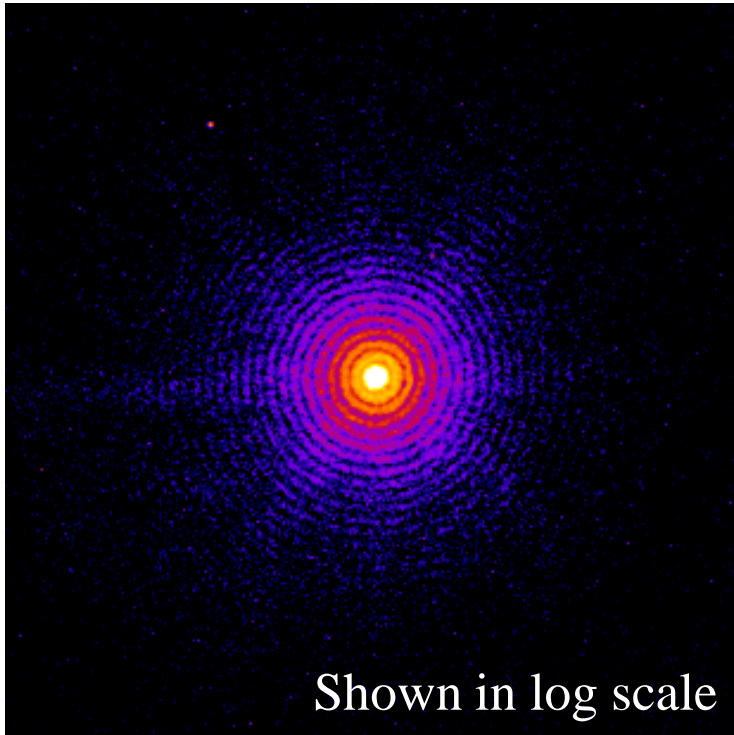
- **Spatial COHERENT**
- **Ultra short pulse**

- **Output EUV (59th)
1 μ W**
- **Divergence:
0.17 mrad**

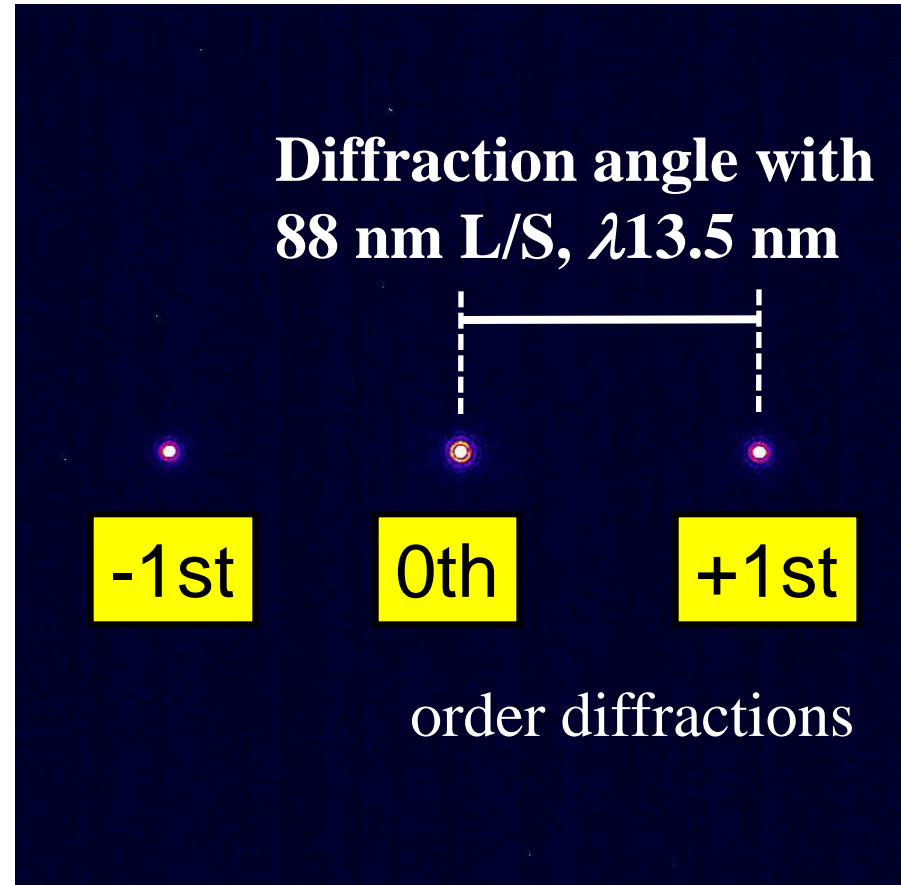
Coherent EUV power
SR $\times 1,000$

Intensity profile with two He pressure conditions.

First light of HHG EUV



Diffraction image without pattern
(Blank region)



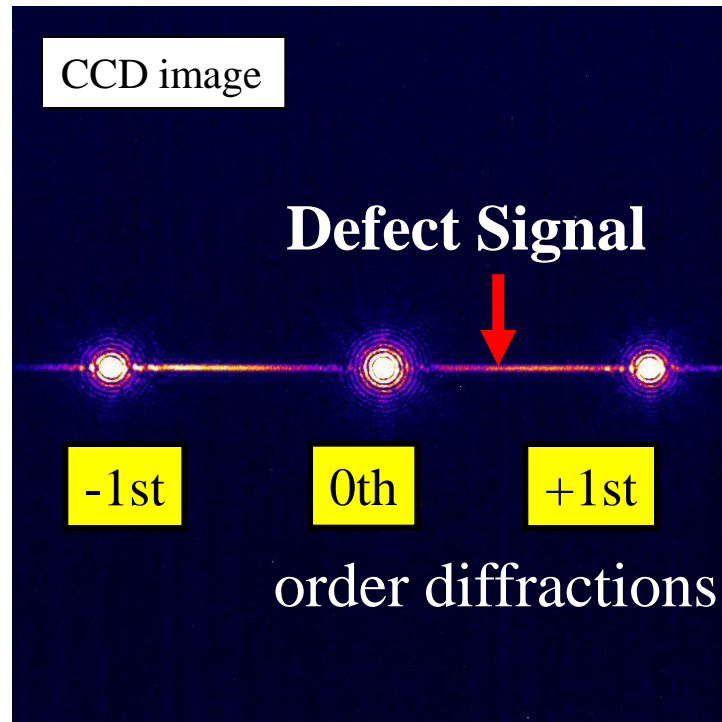
High contrast, low speckle noise

Only 59th generation is recorded.

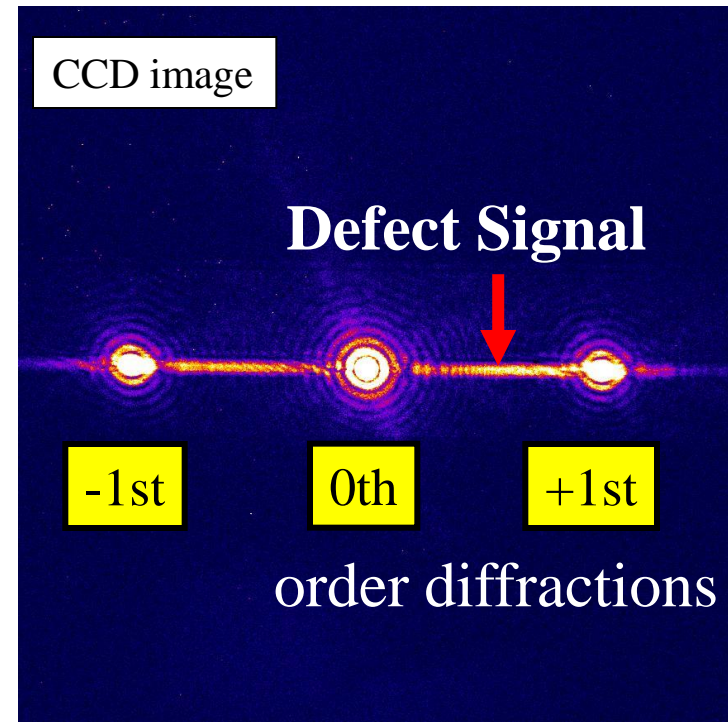
Defect inspection by HHG-CSM system

Sample:

30-nm-wide defect in 88 nm L/S pattern (Programmed defect)



HHG-CSM



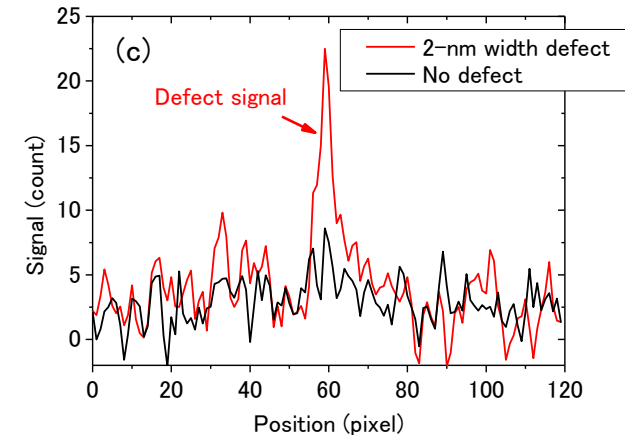
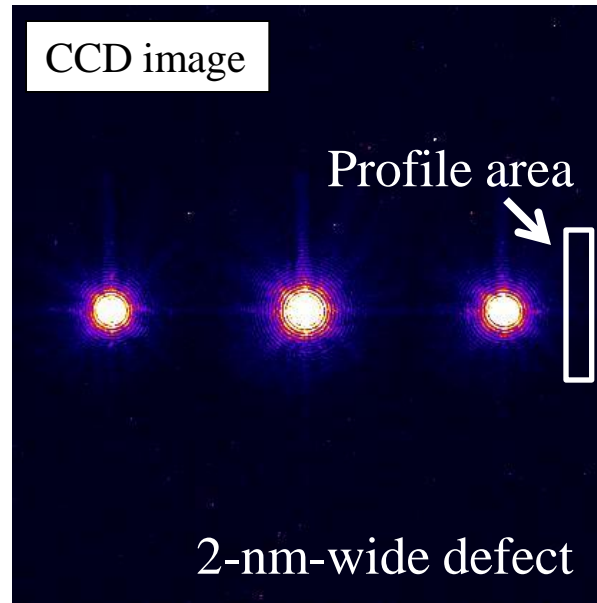
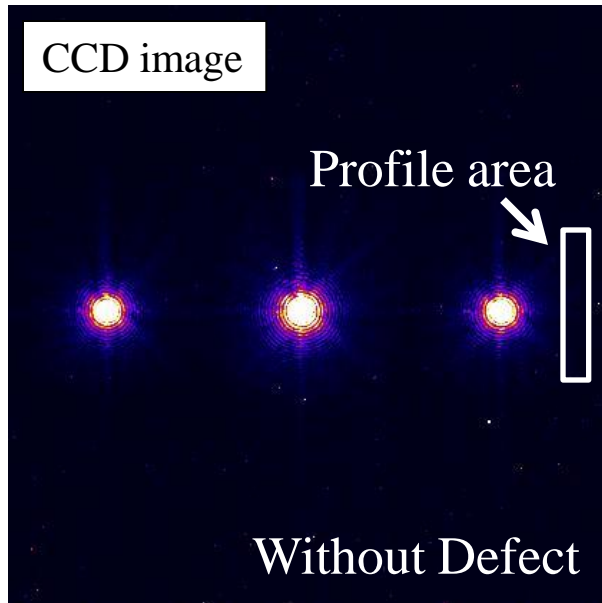
SR-CSM

Defect signal was clearly detected using HHG-CSM

Detection limit of HHG-CSM system

Sample:

2-nm-wide defect in 88 nm L/S pattern (Programmed defect)



Detection limit at SR-CSM: 10 nm

Detection limit is improved to 2 nm with the HHG-CSM system.

Summary

- We developed the CSMs for EUV mask evaluation.
- We developed the algorithms to reconstruct the pattern, to detect the defect, and to evaluate the CD values.
- HHG EUV source was developed for standalone CSM system.
- Using the HHG-CSM system, the detection limit of defect size was improved from 10 nm with SR-CSM system to 2 nm.
- EUV Microscope attached a magnified optics improved the pattern resolution .

